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A revisited conceptualization of plastic pollution accumulation in marine environments: Insights from a social ecological economics perspective

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ABSTRACT

The proliferation of synthetic polymer fragments in marine ecosystems has become a prominent issue within recent years, and its disastrous implications on marine species as well as associated social and economic costs have been extensively documented. A narrow perspective of analysis has characterized current conceptualizations of the phenomenon, which is further resembled in the proposed approaches to tackle the problem. Based on a critical realist philosophy of science, this article aims to investigate the fundamental and interdisciplinary dynamics underpinning the current production, consumption and post-consumption lifecycle of plastics, by abstracting transfactual relationships. These then provide the basis to develop a conceptual model for understanding the phenomenon in a more comprehensive manner, and form a framework to assess proposed policy responses for addressing the issue. Thereby the conceptual model draws upon four fields of knowledge: (i) thermodynamic laws and its relevance for economics, (ii) behavioral psychology and resulting limitations of individuals' decision-making under conscious consumer theory, (iii) power theories of political science, and (iv) ethical considerations. The article suggests that ontological and epistemological discrepancies across disciplines, as well as the consequential neglect of several mechanisms have so far limited scientific progress to guide meaningful political action.

1. Introduction

The excessive use of (single use) plastics and its improper disposal have caused plastic pollution in marine environments to become a major ecological challenge within recent years, implying a plethora of environmental, social and economic ramifications [1]. While marine plastic pollution clearly shows properties of being a global interdisciplinary issue, the current academic debate has been characterized by primarily mono-disciplinary applications, focused on very detailed components of the issue. So far, much attention has gone into monitoring and quantifying the abundance of litter, as well as modeling the paths of debris through ocean currents e.g. [2–7]. At the same time natural sciences continuously reveal new evidence concerning the material's negative implications, such as the disclosure of new species that are affected [8–10], or further ramifications for human health [11–13], effects which are more abundant with the accumulated amount increasing [10]. With regards to solutions to the problem, however, natural sciences remain widely ambiguous. From a legal perspective the issue has been examined focusing on the effectiveness of legal institutions and why legal instruments currently in place have allowed for only limited success. Furthermore, the application of legal institutions in local contexts, such as bans on disposable plastic products (e.g. plastic bags), have been subject to scientific investigations [14,15]. Economics' stance towards plastic pollution has been mainly restricted to quantifying the consequences of marine litter [16], and to the study of price adjustments to internalize the social costs of plastics e.g. [17,18], which relies upon market fundamentalism in its approach. Thereby, such analyses presume naive assumptions about societal change, relying upon the tenets of neoclassical economic theories, despite the profound critique that has been addressed towards this perspective to conceptualize anthropogenic ecological issues, and to capture real world dynamics on both micro and macro level [19,20]. Yet, the academic discourse is characterized by the absence of profound interdisciplinary analytical inquiries that aim to better address the interdependencies between economic and ecological systems. While other ecological challenges, such as climate change, have been discussed by heterodox economists e.g. [21], marine plastic pollution has not yet been taken up as a relevant issue.

This paper argues that current conceptualizations of the problem frequently result in reductionist illustrations of the problem, where major mechanisms that constitute a root of the problem tend do be ignored or sidelined to naïve and simplistic explanations. It proposes that ecological economics, and more general, a critical realist philosophy of science represent a more realistic trajectory to analyze the

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issue. The paper further suggests that this reductionism affects the conceptual understanding and in turn influences the proposed approaches to address the problem. Section 2 discusses critical realism and ecological economics as promising frameworks for scientific explorations, and its role in sound interdisciplinary research. Section 3 then raises several concepts from different disciplines that have so far been neglected, before Section 4 draws conclusions.

2. Philosophy of science

2.1. Critical realism

"Scientifically significant generality does not lie on the face of the world, but in the hidden essence of things" [22:217]. While basic assumptions about the philosophy of science underpinning a research endeavor frequently remain implicit, laying them out can countervail the tendency to end up in naïve empiricist explanations [23], which would be incapable of considering the complex dynamics and underlying mechanisms that make up reality [24:42–45]. According to a critical realist philosophy of science, reality is complex, changing, temporal, and exists independently of human consciousness [25]. On an ontological level, three different domains need to be differentiated, namely the 'real' (the underlying structures and mechanisms), the 'actual' (the events and non-events they create and prevent), and the 'empirical' (the experiences that are observable) [22:2]. Thereby critical realism acknowledges that 'real objects' can only be conceptualized as 'thought objects', and thus the theory-laden character of knowledge, as well as the fact that knowledge is always fallible [23].

Following the mode of reductive interference of Danermark et al., this article asks the question "What conditions make X possible?" [25:97], where X represents the phenomenon under investigation. The question of what constitutes the phenomenon (i.e. marine plastic pollution) will be answered by looking at underlying structures and mechanisms. A comprehensive literature review is undertaken to provide the basis for identifying transfactual relationships, which build the foundations for the development of a conceptual model of the current dynamics and mechanisms regarding both plastic production and consumption, as well as its post-consumption dynamics. While a detailed and comprehensive model is not intended (and contradicts the epistemic understanding of critical realism), the model rather aims at incorporating some key mechanisms that represent important prerequisites without which the phenomenon cannot exist.

"Nature is […] a multiplicity of mechanisms jointly producing the course of events. So the course of events is in principle explicable, but not in terms of any one science" [24:46]. Hence, to meaningfully understand these multiple strata (i.e. ordered layers of nature), each of which shows characteristics of emergence, the phenomenon of marine plastic pollution should be looked at from a variety of perspectives, allowing for different disciplinary insights to be acknowledged as relevant parameters of the model. This is specifically relevant, as "[…] disputes between different scientific disciplines regarding the preferential right of explanation appear to result from a lack of understanding of strata and emergence, which is also the reason for the tendency to come up with single-factor explanations" [25:63]. The conceptual model thus aims to understand basic mechanisms of the complex challenge of marine plastic pollution, its origins and implications, by drawing upon concepts and insights across disciplinary boundaries that complement one another to form a more comprehensive model for understanding the very problem.

2.2. Ecological economics

While some appraisals aim to take a multidisciplinary perspective on plastic pollution e.g. [26], they frequently remain uncritical towards the tenets of neoclassical economics. Such analyses then rest upon the triple-bottom-line definition of sustainability, which seems to be a pragmatic ontological explanation, contradictory to the co-evolutionary and emergent dynamics the problem exhibits, and to Passet's [27] concept of embeddedness, wherein economics denotes a sub-system of the social sphere, which is further embedded in the biophysical world. Standard optimization models often assume an idealized and linear functioning of complex coastal and marine ecosystems [28]. Analyses that are based upon such contradictory ontologies with regards to the integration of ecology and economics substantially limit a constructive epistemic undertaking. This underscores the importance of laying open such ontological presuppositions and 'preanalytic visions' see [29]. Thus, to attain a fruitful analysis of nature-economy interactions, a shift in this preanalytic vision (and a differentiated conceptualization of the problem) is required, from one primarily translating ecological meanings into monetary terms, to one that embraces the interrelatedness of ecological and economic systems, and the existence of biophysical limits [30].

A variety of non-economist researchers engaged in the discourse of marine plastic pollution have highlighted the inherent societal and economic nature of the phenomenon and identified the current production, consumption and post-consumption patterns as relevant parameters of the problem e.g. [31–36]. Yet, the role of economics in the discourse has been rather superficial, and restricted to quantifications and monetizations of the implications of marine debris or to cost-benefit analyses, which aim at internalizing costs and improving the functioning of the market [16–18]. This market-fundamentalist approach omits both the critique of the current paradigm to realistically grasp real world challenges, due to its contested axioms of perfectly informed, rationally behaving individuals [37], as well as scientific progress and lessons learned in other ecological challenges, such as climate change or biodiversity loss [21,38].

It has been suggested that the field of ecological economics provides a suitable framework to comprehend evolutionary complexities and govern marine ecosystems [28,30,39]. In general, it has been pointed out that ecological economics can better grasp the interdependencies between ecological, social and economic spheres than prevailing neoclassical theory, and has thus been applied to investigate other issues, where human (economic) activity has been the primary cause of environmental destruction [40]. Ecological economics has emerged from both economics and ecology and is thus distinct from environmental economics, a sub-branch of neoclassical economics, where the rational of equilibrium analysis is applied to environmental issues [41]. Given its interdisciplinary foundation and the acknowledgement of the importance of methodological pluralism,[1] ecological economics has the potential to overcome strict artificial disciplinary boundaries, without contradictions on ontological presuppositions of ecological and economic spheres [42]. This forms a more holistic approach, and one that acknowledges the notion of complex systems, co-evolution, emerging properties, irreducible uncertainties, and the inherent non-linear characteristics of ecological systems [28]. This broad and interdisciplinary approach, integrating social and natural sciences, is required to arrive at a meaningful analysis of ocean governance [30].

3. Multidisciplinary insights for understanding marine plastic pollution

This section raises a variety of key concepts and perspectives from different disciplines, which can meaningfully enrich and broaden the discourse, and present a more accurate picture of the real world dynamics. Specifically, the chapter will look into (i) the implications of biophysical boundaries on the plastics economy, the structure and

[1] Spash [42] has emphasized the importance of a hierarchical philosophy of science (i.e. ontology, epistemology, methodology, methods) to prevent eclecticism, where contradictory elements on an ontological level render a consistent scientific undertaking impossible.

agency dualism in the context of societal change, where (ii) psychological aspects, as well as (iii) the concept of power provide important key insights, and concludes by discussing (iv) several major ethical issues that are present within the marine plastic pollution discourse.

3.1. Biophysical reality

The shallow application of economics in the plastic pollution discourse results from the problematic assumption of prevailing economic theory with regards to its connection to the biophysical world. In neoclassical theory, economics is treated as an isolated system, divorced from any biophysical reality. Much existing thinking of marine resources has been in line with such economics, "[…] where biophysical limits are axiomatically assumed not to exist, or are, at least, not important" [28:14]. However, the notion that physical limits exist for the economic system has been raised repeatedly e.g. [43–45]. Georgescu-Roegen [46,47] has provided the most substantial analysis by pointing out the relevance of the laws of thermodynamics on the economic process and its implications for planetary boundaries on economic activity. Specifically, The Second Law of Thermodynamics ('The Entropy Law'), and entropy as a measure of the disorder of a system is highly relevant with regards to the economy [46]. Georgescu-Roegen's research reveals crucial insights to the notion of material throughput and processes of irreversible qualitative change as a necessary condition of economic activity. His investigation suggests that limitations exist to material recovery, because recycling requires energy input and can never be perfect [28]. As a result, the economic process inherently transforms economic resources (low entropy) into waste (high entropy) [46]. Although this critical insight of continuous qualitative change within the economic process is often sidelined by orthodox economics (and waste tends to be absent in production function of producers), "[…] economists could not fare continuously well without some solid understanding of the Entropy Law and its consequences" [46:352], as it provides the basis of the economic problem – the scarcity of resources.

With regards to plastics specifically, these physical principles have some crucial implications. Theoretically – if the knowledge and sufficient energy were available – complete recycling would be possible according to the laws of physics. However, this would require an extraordinary amount of energy, which would cause a tremendous net increase in the entropy of the biosphere as a whole, which could not be considered a sustainable solution to the problem [48]. This means that any circularity can only apply to an individual company, or a group of economic actors aiming for a more efficient use of resources. On the aggregate level, however, the 'circular subsystem' represents only a fraction embedded in the system as a whole, which remains heavily dependent upon other parts of the whole system that are not in line with the notion of a circular economy. In addition to these theoretical constraints, synthetic polymers exhibit several practical limitations in the recycling process, such the considerable diversity in polymers and their low melting point, which poses further challenges to separation and recovery and requires a significant energy input to purify the materials.

3.2. Consumerism and behavioral psychology

Marine pollution associated with the excessive use of plastics has been portrayed as a behavioral problem, rather than an implication of the inherent material properties [49], conveying the impression that its solution is to be found within societal change. Frequently, analytical enquires about the consumers' behaviors follow the idealist model of 'homo oeconomicus' who adopts purchasing decisions in the marketplace based on utility-maximization. This Walrasian equilibrium model of neoclassical economics is prevalent in most of economics, but "inconsistent with theories of modern psychology and empirical evidence" [50:227]. It has been argued that the utilitarian approach is contradictory in terms of the conceptualization of time, habits, and the role of emotions in decision processes [51–53], and widely ignores recent advances made in fields like (social) psychology, neuroscience and sociology [37]. In the context of other ecological issues, considerable literature has looked into 'ethical' consumer behavior e.g. [54–56], investigating purchasing decisions with regards to products that reduce the environmental pressure of consumption (e.g. organic products), as well as associated cognitive processes and motivations behind them.

Consumption activities have increasingly become a means of self-identity construction [57]. This relates to the 'self-concept', wherein an individual tries to define their identity through their actions [58]. This framework explains how feelings as well as emotions build the basis for the individual's actions [59]. In general, consumers do not only strive for a mere hedonistic and immediate utility-maximization at all costs as suggested by orthodox utility theory, but also have long-term higher-order goals (e.g. ethical foundations), which frequently contradict short-term lower-order preferences [54]. These short-term influences are competing priorities (e.g. convenience, price), which can prevent the ethical purchasing alternative from being realized, and result in contradictory behaviors of consumers concerning their ego-ideal creating cognitive dissonances [60]. According to dissonance theory, a person experiences discomfort and mental stress, when he/she holds two or more contradictory beliefs or values at the same time [61]. Cognitive dissonances are said to be the greatest and clearest when not just any two contradicting cognitions are involved, but when they concern the self and violate the self-concept [62]. To cope with the psychological displeasure, the theory claims that a person will aim to re-establish consistency and balance [61]. Therefore, consumers are said to track their purchasing decisions in cognitive categories ('mental accounts'), where they account separately for positive and negative emotions [63]. Ethical purchases then compensate for future unethical consumption decisions (and vice versa) [56].

Furthermore, other cognitive peculiarities need to be mentioned in this context, such as heuristics and their role in decisions that are often based on rules of thumb rather than strict logic [53], or consumers' preference for immediate interests over gains that lie far in the future when making (purchasing) decisions [51,64]. In addition, context can have a vast impact on purchasing decisions, and can heavily affect how planned behaviors are actualized under real life consumption conditions [65,66]. Habits, inherited behaviors, and social influences further contribute to deviations in real life consumption behavior from the idealized green consumerist model [52].

Consumption fundamentally affects the motivational structure of the human mind, where intrinsic motivations to create a better world (and advance towards the ego-ideal) may be crowded out by extrinsic motivations to initiate change [67]. Even if a transcendental goal of consumers exists to create a better world via their purchasing decisions, by propagating individualized ethical market decisions and consumerism as appropriate means to foster change, ethical consumerism diverts the attention from collective forms of political action and civic engagement, which are necessary to create an ecologically sound and socially just world [68].

3.3. Political theory

Limitations to human agency do not only exist in terms of cognitive and psychological processes, but also with regards to the macro perspective of societal structures. Numerous intellectuals, from ancient philosophers to Thomas Hobbes, Niccolò Machiavelli, and more recently Dahl [69] and Foucault [70] have been devoted to investigating the meanings of 'power', which denotes a key concept in the social sciences [71]. In its simplest definition, power is often regarded as primarily coercive nature, where "A has power over B to the extent that he can get B to do something that B would not otherwise do" [69:202f]. Yet this view on power has been gradually expanded as the complexity of the concept has increasingly been appreciated. Therefore, definitions moved beyond the actor-centered, and possessive, to consider its

enabling and structural dimensions.[2]

The current system of easily available and disposable plastics supports the interests of multi-billion corporations. In Europe, 1.45 million people are directly employed by the plastics industry, which includes 62,000 companies, generating a turnover of €350 billion, with further multiplier effects to GDP and indirect employment potential [72]. Globally, the concentration of powers is even more significant. Plastics account for roughly 6% of global crude oil consumption, which equates to the demand of the global aviation industry [73], and its manufacture requires an additional 4% [49]. If current trends continue, plastics are expected to account for about 20% of global oil consumption, and 15% of the yearly global carbon budget to stay within the 2 degrees threshold [73].

The notion of power illustrates the innate tendency of the industry fighting fiercer regulation in an attempt to keep their room for maneuver as unrestricted as possible and to ensure the continued existence of the industry. Dahl's [69] episodic understanding of power as a means of coercion can help to explain how immense power concentrations become manifest in their fundamental capacity to influence legislation (e.g. through lobbying efforts). These prevalent power imbalances further enable actors to take an active role in agenda-setting, the second dimension of power [74] and relate to the fact that there are few available products that are not comprised of some polymer or/and are not packaged in plastics [31]. Another example of this dimension of power would be the corporate funding and active involvement in the writing of scientific studies by organizations, which benefit from readily available and disposable plastics. Lukes' [75] third dimension of power, which refers to 'preference-shaping', relates to an even more subtle form of power execution, where the real interests are disguised by perceived interests, without the consciousness of the dominated.

Power asymmetries between the plastics industry and individuals (as both consumers and citizens) become even more obvious upon critical reflection of 'consumer sovereignty', which refers to the concept that consumers ultimately decide upon the products to be produced and sold in the marketplace [76]. However, the validity of such a concept has been challenged in a significant amount of literature e.g. [77,78]. It has been suggested that the belief in this concept's validity prevents the analysis of urgent political challenges, as consumers are understood to be responsible for economic activity, outputs and undesirable concomitant effects, such as pollution [79]. The conceptualization of consumers' role in the marketplace resembles the hegemonic way in which sustainability challenges are conceptualized and environmental problems are tackled, namely by shifting the responsibility from the state to the individual consumer [80]. This privatization and commodification of sustainability through the consumption of 'ethical products' has become a ubiquitous imperative in the economic reality and media, which gives the impression that political efforts have failed or at least paled and thus sustainability shifted to the sphere of private action [80]. However, the assumption that social change occurs as a result of the sum of individual behaviors resembles the misleading atomistic ontological claim that the whole simply consists of the sum of its parts, while in fact holism (i.e. the whole is more than simply the sum of its parts) represents a more realistic conceptualization [81]. This model, where the marketplace is understood as the dominant ground for change, and which by definition brings self-interest to the forefront, distracts attention from substantive collectivist approaches to meaningful change.

The historical success of the material plastic can be linked with the support of a variety of institutions, which have enabled the mushrooming of plastic products with modernity, such as the announcement of 'throwaway living', communicated as an opportunity to increase leisure time through disposability [35,82]. Its properties of low weight, moldability, as well as low costs, have caused the emergence of plastic products as a symbol of the throwaway society, so that plastics have served as a supporter of globalization [35], the neoliberal policy agenda and an economic system that is largely based on perpetual growth. A great number of industries benefit from having plastics as an available option for their business operations, although at the expense of other species and future generations. For instance, substituting glass bottles with alternatives made from PET is expected to save 52% in transportation costs [49], which is why the material has been a significant enabler of long-distance trade. Hence, a critical investigation into the plastic pollution crisis cannot go without a critique of the current economic system shaped by the neoliberal narrative of relentless free trade and deregulation. A thorough analysis of the problem could go on to contextualize these institutions in an historical context, and investigate how plastics have manifested themselves in a variety of institutions and behavior patterns (e.g. throwaway living). A less plastic-intensive economy would revolutionize the global economic order, foster localized production and consumption due to higher logistical costs, questions certain industries, and more generally the neoliberal dogma of economic organization.

3.4. Ethical considerations

The underlying dynamics of marine litter appear to show some conceptual similarity with other phenomena at the economy-ecology nexus with regards to their ethical implications, such as climate change [83]. Thereby the issue affects several key ethical dimensions, such as the conceptualization of efficiency, inherent interregional, intergenerational and interspecies conflicts, as well as the treatment of uncertainties.

Among the major arguments for the need of plastics and associated societal benefits, a substantial part emphasizes its role in terms of efficiency and reduced costs, rather than providing a benefit that can be brought in association with a novelty that arrived with the invention of plastics. While single-use products may be efficient and easy for both producers (low production costs, simple logistics, low weight, flexible moldability for divers needs) and consumers (cheap, disposable, lightweight), the post-consumption phase incurs cost-shifting to the environment and social sphere with yet unforeseeable consequences. If neoclassical economic theory, which by definition promotes market-based institutions above others, is applied to such sustainability issues, its specific methodology applies "a priori theoretical commitments and ideological beliefs – that society should increase consumption" [83:168]. However, this happens without considering that markets make up just one institution of many for societal organization [84]. Furthermore, the argument has been raised that human preferences provide only a poor basis for directing moral action [85]. Neoclassical economic methodology further assumes a commensurable world, where ecological meanings ('natural capital') can be quantified, monetized and substituted with 'financial capital' without explicitly stating that this incurs a strong ethical judgment [83].

In addition, plastics pose challenges to interregional ethics in a variety of ways, most notably as peoples without their involvement see and experience the disastrous negative consequences of unsustainable lifestyles of the affluent throwaway age [86]. This resembles 'the imperial mode of living', which depicts the prosperity of the Global North as a result of the continued self-sustaining of unequal power relationships in the global division of labor, and their use of ecological resources and sinks of the Global South [87]. This conflict rests upon, and is in close relationship to interspecies ethics, as human economic activity shifts the costs of a disposable lifestyle to other species. The irony of this opportunistic behavior, however, lies in the fact that eventually this misunderstanding undermines the source of life for future generations of humans. Marine plastic pollution thus also violates intergenerational equity, as costs in the form of damages to the environment

[2] For a comprehensive overview of power theories in the context of ecological economics see: L. Stoer, Theories of Power, in: C.L. Spash (Ed.) The Routledge Handbook of Ecological Economics: Nature and Society, Abingdon, Routledge, 2017.

are pushed to yet unborn generations.

Finally, scientific progress is facing limits in understanding the uncertainty apparent in the issue, which results in an inadequate way to take precautionary action. The weakness of orthodox theory becomes particularly apparent in the manner complexity and uncertainties are conceptualized and frequently reduced to quantifiable risks. Unlike risk (weak uncertainty) where probabilities to certain outcomes can be assigned, uncertainty (strong uncertainty) is ontologically distinct and refers to non-quantifiable outcomes [88]. Especially in marine ecosystems, strong uncertainty is all-pervasive, as they function in a manner that is inherently non-linear, interdependent, and with somewhat unknown variables, which makes any calculation of probabilistic risks futile [28,30,89]. Fundamental uncertainty will thus persist, "[…] particularly when the problem is framed in broad terms and over longer time-frames and diverse spatial scales" [28:14]. Large uncertainties further remain with regards to marine debris data, such as the quantity of debris entering marine ecosystems, the accumulated amount in the oceans, and encompass much of the dynamics of synthetic polymers in oceanic environments (e.g. interaction with deep-sea sediments and its implications on marine life) [10]. The inclusion of a 'precautionary principle' has thus been identified as particularly relevant for the governance of marine ecosystems [28,30,90,91].

4. Conclusions

In prevailing conceptualizations of marine plastic pollution, a variety of arguments and mechanisms have been widely neglected that are highly relevant in constituting the problem of marine plastic pollution. Based on a critical realist philosophy of science, and the mode of retroductive inference, this article aims to investigate the problem of marine plastic pollution beyond an empiricist position by abstracting transfactual relationships that constitute the domain of the 'real'. Thereby the article set out to raise the relevance of a broader perspective and the integration of different disciplinary insights and concepts, to arrive at a comprehensive conceptualization of what constitutes the very problem.

The global plastic pollution crisis illustrates the inability of prevailing economic theory to grasp and address real world challenges and its incompatibility with the complexity of ecological systems, by relying on simplistic assumptions and applying heavy analytical reductionism to a complex and systematic problem. A social ecological economics perspective, based on a critical realist philosophy of science provides an enriched interdisciplinary viewpoint to understand different strata of reality, and a framework that can investigate the issue without contradictions of ontological presuppositions. The multidisciplinary insights raised represent a 'condicio sine qua non' for a profound analysis of the issue, and its disregard means ignoring the existing structures of our society, progress made in several relevant disciplines and contributions of well-respected moral philosophers. If, however, these mechanisms remain implicit, it is likely that they remain unconsidered as major constituents of the problem, and that policy responses required maintain superficiality in their approach, unable to consider transformations beyond shallow applications within the current system.

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